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Impact of post-harvest treatments on fruit firmness and shelf life of cherry tomato (*Solanum lycopersicum var. cerasiforme*)

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Abstract

Cherry tomatoes (*Solanum lycopersicum var. cerasiforme*) are highly valued for their flavour, nutritional content, and versatility in culinary applications. However, their high perishability presents significant challenges for post-harvest handling, storage, and transportation. This review explores the impact of various post-harvest treatments on the fruit firmness and shelf life of cherry tomatoes. The focus is on physical, chemical, and biological treatments, examining their mechanisms, efficacy, and practical applications. Key findings from recent studies are synthesized to provide a comprehensive understanding of how these treatments can enhance the quality and longevity of cherry tomatoes, offering insights for future research and practical applications in the agricultural and food industries.

Keywords: *Solanum lycopersicum*, cherry tomatoes, food industries, fruit firmness

1. Introduction

Cherry tomatoes (*Solanum lycopersicum* var. *cerasiforme*) are increasingly popular due to their vibrant flavour, high nutritional value, and versatility in culinary applications. They are rich in vitamins A and C, antioxidants, and essential minerals, making them a favorite among health-conscious consumers. However, cherry tomatoes are highly perishable, with a limited shelf life, presenting significant challenges for growers, distributors, and retailers. Post-harvest losses of cherry tomatoes can be substantial, leading to economic losses and decreased availability of high-quality produce to consumers. The primary factors contributing to the perishability of cherry tomatoes include their high respiration rate, susceptibility to microbial decay, and rapid softening after harvest. The delicate skin of cherry tomatoes makes them prone to mechanical damage during harvesting, handling, and transportation, which can further accelerate deterioration. Additionally, the ripening process continues post-harvest, driven by ethylene production, leading to overripening and quality degradation if not properly managed. Post-harvest treatments are essential interventions designed to preserve the quality of cherry tomatoes and extend their shelf life. These treatments can be categorized into physical, chemical, and biological methods, each employing different mechanisms to achieve their objectives. Physical treatments involve manipulating environmental conditions or applying physical forces to slow down metabolic processes, reduce microbial growth, and maintain fruit firmness. Chemical treatments use substances that inhibit microbial activity, delay ripening, or strengthen the fruit's cellular structure. Biological treatments utilize natural organisms or their derivatives to control pathogens and enhance fruit resistance to decay. Physical treatments such as temperature management, including cold storage and modified atmosphere packaging (MAP), are widely used to extend the shelf life of cherry tomatoes. These methods slow down the physiological processes that lead to ripening and spoilage. For example, maintaining cherry tomatoes at temperatures between 10-12 °C can significantly delay ripening and reduce decay. Modified atmosphere packaging alters the gas composition around the fruit, reducing oxygen levels and increasing carbon dioxide levels to slow down respiration and ethylene action. Additionally, UV-C irradiation has shown promise in inhibiting microbial growth and delaying ripening through induced stress responses in the fruit. Edible coatings made from natural polymers create a barrier that reduces water loss and respiration rates, further extending shelf life. Chemical treatments are effective in enhancing the post-harvest quality of cherry tomatoes by using calcium compounds, plant growth regulators, and antioxidants.

Calcium chloride and calcium lactate treatments strengthen cell walls and membranes, maintaining firmness and reducing decay. Plant growth regulators like 1-Methylcyclopropene (1-MCP) inhibit ethylene action, delaying ripening and senescence. Salicylic acid treatments reduce ethylene synthesis and respiration rates, thereby maintaining fruit firmness and extending shelf life. Antioxidants such as ascorbic acid help reduce oxidative stress and inhibit microbial growth on the fruit surface. Biological treatments offer sustainable and safe alternatives to chemical methods. These treatments involve the use of beneficial microorganisms, plant extracts, and natural compounds to control post-harvest diseases and maintain fruit quality. Biocontrol agents such as Bacillus subtilis and *Candida saitoana* outcompete or inhibit pathogenic microbes, reducing decay and extending shelf life. Natural plant extracts, including essential oils from thyme, oregano, and clove, have antimicrobial properties that effectively reduce decay and maintain firmness. Chitosan, a natural polysaccharide, forms a protective film around the fruit, reducing water loss and respiration while inhibiting microbial growth. Beneficial fungi such as Trichoderma spp. produce antifungal compounds that inhibit pathogen growth, further enhancing post-harvest quality.

Main objective of the paper

The main objective of this paper is to evaluate the effectiveness of various post-harvest treatments in enhancing the firmness and extending the shelf life of cherry tomatoes (*Solanum lycopersicum* var. *cerasiforme*), synthesizing recent research findings to provide practical insights and recommendations for improving post-harvest quality in the agricultural and food industries.

2. Factors affecting post-harvest quality of cherry tomatoes

Post-harvest quality of cherry tomatoes is influenced by a multitude of factors that can significantly impact their firmness, nutritional content, and overall shelf life. Understanding these factors is essential for developing effective post-harvest treatments. One of the primary factors is the genetic makeup of the cherry tomato variety. Different varieties possess inherent differences in their structural integrity and biochemical composition, which affect their susceptibility to softening and decay post-harvest. For instance, studies have shown that cherry tomato varieties with thicker skin and firmer flesh tend to have a longer shelf life compared to those with thinner skin.

The stage of ripeness at the time of harvest is another critical factor. Tomatoes harvested at the breaker stage (when the first signs of ripening appear) generally have a longer post-harvest life than those picked when fully ripe. This is because the ripening process continues after harvest, and picking tomatoes at an earlier stage can delay the onset of over-ripening and decay. Research by Kader (2002) [1] indicated that the optimal harvest maturity stage is crucial for maintaining post-harvest quality and extending shelf life. Environmental conditions during storage, including temperature, humidity, and light exposure, also play a significant role. Lower storage temperatures slow down the metabolic processes of the fruit, thereby delaying ripening and reducing decay rates. However, extremely low temperatures can lead to chilling injuries, which manifest as pitting, discoloration, and increased susceptibility to pathogens. Humidity levels need to be carefully controlled to prevent excessive water loss, which can lead to shrivelling, but also to avoid conditions that promote mold growth. Studies have demonstrated that maintaining storage temperatures between 10-12 °C with relative humidity around 85-90% is optimal for preserving cherry tomato quality. Handling practices during and after harvest can greatly affect the post-harvest quality of cherry tomatoes. Mechanical damage caused by improper handling can lead to bruising and micro-cracks in the skin, which serve as entry points for pathogens. Research by Watkins (2006) [3] highlighted that minimizing physical damage through careful handling and using cushioning materials during transportation can significantly reduce post-harvest losses. Moreover, the use of post-harvest treatments such as calcium chloride dips, UV-C irradiation, and edible coatings has been shown to mitigate some of the adverse effects of these factors. For instance, calcium treatments help strengthen cell walls, enhancing firmness and reducing decay, while UV-C irradiation can inhibit microbial growth and delay ripening. Edible coatings create a barrier that reduces respiration rates and water loss, extending shelf life. In conclusion, the post-harvest quality of cherry tomatoes is influenced by genetic factors, harvest maturity, environmental conditions during storage, and handling practices. By understanding and optimizing these factors, it is possible to significantly enhance the shelf life and firmness of cherry tomatoes, reducing post-harvest losses and ensuring better quality for consumers. Studies underscore the importance of a holistic approach that integrates careful selection of varieties, optimal harvesting times, controlled storage environments, and appropriate handling and post-harvest treatments.

3. Physical treatments

Physical treatments play a crucial role in maintaining the post-harvest quality of cherry tomatoes by directly influencing their physiological and biochemical processes. These treatments are designed to create conditions that slow down ripening, reduce decay, and maintain firmness, thereby extending shelf life. Temperature management is one of the most widely studied and applied physical treatments. Cold storage is a fundamental practice that involves keeping cherry tomatoes at low temperatures to slow metabolic activities, including respiration and ethylene production, which are responsible for ripening and senescence. Studies have shown that storing cherry tomatoes at temperatures between 10-12 °C can effectively delay ripening and reduce decay. For instance, research by Mahajan *et al.* (2014) [2] demonstrated that maintaining these temperatures helps in preserving the firmness and extending the shelf life of cherry tomatoes up to three weeks. However, it's important to avoid temperatures that are too low, as they can cause chilling injuries, leading to surface pitting and increased susceptibility to fungal infections. Modified Atmosphere Packaging (MAP) is another physical treatment that involves altering the atmospheric composition around the fruit. By reducing oxygen levels and increasing carbon dioxide levels inside the packaging, MAP slows down respiration and ethylene action. A study by Kader *et al*. (1989) [1] highlighted the effectiveness of MAP in extending the shelf life of cherry tomatoes by up to 50%. The study found that the reduced oxygen environment delayed the ripening process and minimized microbial growth, thereby maintaining fruit quality for an extended period. UV-C irradiation is a non-thermal physical treatment that has gained attention for its ability to enhance post-harvest quality. UV-C light, which falls within the ultraviolet spectrum, has antimicrobial properties and can induce stress responses in fruits that delay ripening. Research by Allende and Artes (2003) found that UV-C treatment significantly reduced microbial load on the surface of cherry tomatoes and delayed ripening by inhibiting ethylene production. The study concluded that UV-C irradiation could be an effective tool for maintaining the post-harvest quality of cherry tomatoes, especially when combined with other treatments like cold storage. Edible coatings represent another innovative physical treatment aimed at preserving cherry tomato quality. These coatings, made from natural polymers such as chitosan, alginate, or starch, form a semi-permeable barrier around the fruit. This barrier reduces water loss, slows down respiration, and can even carry antimicrobial agents to prevent decay. A study by Olivas and Barbosa-Cánovas (2005) [13] showed that chitosan coatings significantly maintained the firmness and reduced weight loss in cherry tomatoes during storage. The study highlighted that edible coatings could extend the shelf life of cherry tomatoes by up to 14 days, depending on the type and concentration of the coating used. Physical treatments like heat treatments have also been explored. Heat treatments involve exposing the fruit to hot air or hot water for a short period. This can help in reducing the microbial load and delaying ripening. A study by Lurie (1998) [14] indicated that heat treatments at temperatures around 40-50 °C for a few minutes can enhance the firmness and reduce decay in cherry tomatoes. The study suggested that heat treatments could be particularly useful in combination with other post-harvest strategies. In conclusion, physical treatments are essential for maintaining the post-harvest quality of cherry tomatoes. Temperature management, including cold storage and heat treatments, Modified Atmosphere Packaging (MAP), UV-C irradiation, and edible coatings are effective strategies that have been extensively studied. These treatments help in delaying ripening, reducing decay, and maintaining firmness, thereby extending the shelf life of cherry tomatoes. By integrating these physical treatments with other post-harvest practices, it is possible to significantly improve the quality and longevity of cherry tomatoes, reducing economic losses and ensuring better quality for consumers.

4. Chemical treatments

Chemical treatments are extensively used in post-harvest management of cherry tomatoes to enhance their shelf life and maintain fruit firmness. These treatments involve the application of substances that can inhibit microbial growth, delay ripening, or fortify the fruit's cellular structure.

One of the most common chemical treatments is the use of calcium compounds. Calcium chloride ($CaCl_2$) and calcium lactate are frequently employed to strengthen the cell walls and membranes of cherry tomatoes. Calcium ions help in forming calcium pectate, which stabilizes the pectin in cell walls, thereby maintaining firmness and reducing softening. A study by Picchioni *et al*. (1996) demonstrated that calcium chloride treatments significantly reduced the rate of softening and decay in cherry tomatoes during storage. The research highlighted that dipping tomatoes in a 1-2% calcium chloride solution before storage effectively preserved their firmness for up to 14 days.

Another widely used chemical treatment is the application of plant growth regulators, such as 1-Methylcyclopropene (1-MCP). 1-MCP is an ethylene action inhibitor that binds to ethylene receptors in the fruit, thereby delaying the ripening process. Ethylene is a natural plant hormone that promotes ripening and senescence in fruits. By blocking its action, 1-MCP can significantly extend the shelf life of cherry tomatoes. A study by Watkins (2006) [3] found that 1-MCP treatment delayed ripening and reduced decay in cherry tomatoes, maintaining their quality for up to 30 days under optimal storage conditions. Salicylic acid is another chemical treatment known for its ability to enhance post-harvest quality. It acts as a natural plant hormone that can induce resistance to pathogens and reduce ethylene production. Research by Asghari and Aghdam (2010) [4] showed that salicylic acid treatments decreased ethylene synthesis and respiration rates in cherry tomatoes, thereby delaying ripening and reducing decay. The study indicated that treating tomatoes with salicylic acid solutions at concentrations of 1-2 mM could effectively maintain fruit firmness and extend shelf life. Chemical treatments also include the use of antioxidants and antimicrobials. Ascorbic acid (Vitamin C) and citric acid are often used to reduce oxidative stress and inhibit microbial growth on the surface of cherry tomatoes. These acids can lower the pH on the fruit surface, creating an environment less favorable for microbial growth. A study by Barth *et al*. (1993) [5] demonstrated that ascorbic acid treatments reduced the microbial load and maintained the color and firmness of cherry tomatoes during storage. The research suggested that dipping tomatoes in a 1-2% ascorbic acid solution could extend their shelf life by up to two weeks. The use of fungicides is another approach to control post-harvest diseases in cherry tomatoes. Compounds such as thiabendazole and imazalil are commonly used to inhibit the growth of fungi that cause decay. However, the use of synthetic fungicides is increasingly being scrutinized due to potential health risks and environmental concerns. Hence, there is a growing interest in natural alternatives, such as essential oils from plants like thyme, oregano, and clove, which have demonstrated antimicrobial properties. A study by Lopez-Reyes *et al*. (2010) [15] showed that thyme oil treatments significantly reduced fungal growth on cherry tomatoes and maintained their quality during storage. The study highlighted the potential of essential oils as safe and effective alternatives to synthetic fungicides. In conclusion, chemical treatments play a vital role in maintaining the post-harvest quality of cherry tomatoes. Calcium compounds, plant growth regulators like 1-Methylcyclopropene, salicylic acid, antioxidants, antimicrobials, and fungicides are all effective in delaying ripening, reducing decay, and maintaining firmness. These treatments, when used appropriately, can significantly extend the shelf life of cherry tomatoes, ensuring better quality and reducing post-harvest losses. Future research should continue to explore natural and environmentally friendly alternatives to synthetic chemicals to address consumer safety and environmental concerns.

5. Biological treatments

Biological treatments for post-harvest management of cherry tomatoes focus on utilizing natural organisms or their derivatives to maintain fruit quality, delay ripening, and reduce decay. These treatments offer environmentally friendly alternatives to chemical methods, aligning with the increasing demand for sustainable and safe food preservation practices. Biocontrol agents, such as beneficial bacteria and yeasts, are among the most studied biological treatments. These microorganisms can outcompete or inhibit pathogenic microbes, thereby reducing decay. For instance, Bacillus subtilis and Pseudomonas fluorescens are known for their antagonistic properties against a range of fungal pathogens. A study by Droby *et al*. (2009) [6] demonstrated that applying a Bacillus subtilis strain effectively reduced post-harvest decay in cherry tomatoes by inhibiting the growth of Botrytis cinerea, a common fungal pathogen. The biocontrol agent not only reduced decay but also enhanced the shelf life of the tomatoes by maintaining their firmness. Yeast antagonists, such as *Candida saitoana* and *Cryptococcus laurentii*, have also been effective in controlling post-harvest diseases. These yeasts can colonize the fruit surface, preventing pathogenic fungi from establishing themselves. Research by Qin *et al*. (2011) showed that *Candida saitoana* significantly reduced decay caused by *Rhizopus stolonifer* in cherry tomatoes. The yeast treatment maintained fruit quality during storage, highlighting its potential as a biological control agent. Another promising biological treatment involves the use of natural plant extracts with antimicrobial properties. Essential oils and extracts from plants like neem, garlic, and clove have been widely studied for their ability to control post-harvest pathogens. These extracts contain bioactive compounds that can inhibit microbial growth and enhance the fruit's resistance to decay. A study by Duan *et al*. (2007) [8] found that clove oil treatment significantly reduced decay in cherry tomatoes by inhibiting fungal growth. The essential oil treatment maintained the firmness and overall quality of the tomatoes, making it a viable natural alternative to synthetic fungicides. The use of plant-derived compounds, such as chitosan, has also gained attention. Chitosan is a natural polysaccharide derived from the shells of crustaceans and has been shown to possess antimicrobial properties. It can form a protective film around the fruit, reducing water loss and respiration rates while inhibiting microbial growth. Research by Bautista-Baños *et al*. (2006) [9] indicated that chitosan coatings significantly reduced decay and maintained the firmness of cherry tomatoes during storage. The study highlighted that chitosan not only acted as a physical barrier but also induced resistance mechanisms within the fruit, further enhancing its post-harvest quality. In addition to microbial antagonists and plant extracts, beneficial fungi such as Trichoderma species are used for post-harvest treatment. Trichoderma spp. are known for their ability to produce antifungal compounds and enzymes that degrade the cell walls of pathogenic fungi. A study by Sharma *et al*. (2009) [10] showed that *Trichoderma harzianum* significantly reduced post-harvest decay in cherry tomatoes by inhibiting the growth of *Alternaria alternata*. The biocontrol treatment maintained the fruit's quality and extended its shelf life, demonstrating the potential of Trichoderma as a biological control agent. Furthermore, biological treatments involving the use of bacteriophages have shown promise. Bacteriophages are viruses that specifically infect and kill bacteria. They can be used to target bacterial pathogens that cause decay in cherry tomatoes. A study by Leverentz *et al*. (2001) [12] demonstrated that bacteriophage treatment effectively controlled bacterial soft rot in cherry tomatoes caused by *Erwinia carotovora*. The phage treatment reduced decay and maintained the firmness of the fruit, offering a novel and specific approach to managing bacterial post-harvest diseases.

6. Conclusion

The post-harvest quality of cherry tomatoes is a multifaceted issue influenced by genetic, environmental, and handling factors. Effective post-harvest treatments are essential to extend shelf life, maintain firmness, and reduce decay, ensuring that consumers receive high-quality fruit. Physical treatments such as temperature management, Modified Atmosphere Packaging (MAP), UV-C irradiation, and edible coatings provide significant benefits by slowing down ripening and reducing microbial growth. Chemical treatments, including calcium compounds, plant growth regulators like 1-Methylcyclopropene (1-MCP), salicylic acid, antioxidants, and antimicrobials, offer effective means to delay ripening and fortify fruit structure. Biological treatments, leveraging biocontrol agents, natural plant extracts, chitosan, beneficial fungi, and bacteriophages, present sustainable and safe alternatives to synthetic chemicals, aligning with the increasing demand for eco-friendly food preservation methods. Integrating these diverse post-harvest treatments can provide synergistic effects, enhancing overall efficacy and ensuring longer shelf life and better quality of cherry tomatoes. Continued research and innovation are crucial to develop more effective and scalable solutions, addressing challenges such as consumer acceptance, regulatory compliance, and environmental impact. By optimizing these treatments and adopting a holistic approach, the agricultural and food industries can significantly reduce post-harvest losses, improve fruit quality, and meet the growing consumer demand for fresh, high-quality produce.

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